The Three Pillars of Success for Aviation and Space Transportation in the 21st Century

a Speech before the Aero Club, AIAA, and NAC
by NASA Administrator, Daniel S. Goldin

Thursday, March 20, 1997

It is a day in May. May 10th to be exact. The air is electric. It is a sensation - this excitement - unlike any felt before. The spectators have come a long way. Utah. North of the Great Salt Lake, 56 miles west of Ogden. A little place no one's ever heard of before called Promontory Summit.

In the center of the crowd stand several men, and two trains. One heading east, one heading west. The men having their photos taken smile. They are making history and they know it. The year is 1869. The man in the forefront, with the place of honor is Leland Stanford. Businessman, future governor of California, and currently the president of the Central Pacific railroad.

Before him this day are five spikes, two of gold, one of silver, one a blend of gold, silver and iron. But the fifth is a regular spike. And Leland Stanford, the man credited with connecting the east with the west, will personally pound the last spike into place, the ordinary one. It is ordinary, except in one respect, it is wired to a telegrapher's key, and when Leland Stanford hammers it into place, the country will celebrate the first transcontinental railway. America would never be the same.

This is how it's been throughout history, the inextricable link between transportation and communications in opening new frontiers for economic development. With each new development in transporting people and goods, there have been dramatic economic gains.

First there was an era of discovery. The earliest caravans opened trade routes connecting Asia and Europe. Sailing ships discovered new continents, and the shores of this country were opened to exploration and colonization. Covered wagons spurred expansion to the West.

Then Leland Stanford provided the transportation backbone which opened an era of national growth. The railroads and telegraph opened the interior

of the U.S. There was a wealth of natural resources for manufacturing and power. It allowed for an expansion of our workforce, and the rapid transport of people and goods. Then interstate highways and telephones networked the rail system and the rest of the country. We became more diversified. We had transportation for people, and transportation for small and large cargo. The economic gains were two-fold. There was a huge growth in the infrastructure, including motor vehicle and associated industries, and also a huge growth in commerce, using the new communication and transportation systems. After World War II, it took a while for the idea of regular air travel to take hold. But take hold it did. It changed the way we run our lives.

In 1960, the Gross Domestic Product was $515 billion. In 1995, it was $7.2 trillion. That's a 14 fold increase. During the same time, U.S. exports went up almost 30 fold, from $19.6 billion to $584.7 billion. None of that would have happened without consistent, reliable, air transportation and communications. And this is only the beginning.

Air transportation has now become essential to economic progress for the people and businesses of America. Without it we can't participate in the increasingly global marketplace. Air transportation makes it possible to quickly move millions of people and billions of dollars worth of goods to markets around the world. It touches some part of our daily lives from our mail to our fresh produce.

There are no practical alternatives to air transportation.

Now, it's the era of globalization. For the past 30 years aviation has established itself as the preferred mode of high-speed travel. Today, the most rapid industrial growth is in long-haul aviation and in terrestrial and satellite communi-cation systems, spurred by global economic opportunities. Aviation is absolutely crucial to the American economy.

Given the challenge, of getting people and freight safely and efficiently to anywhere in the world, at a reasonable cost --what are the keys to making this happen? First, air travel must be ultra-safe. It must provide around-the-clock reliable service, and be quiet and environmentally friendly. It must also be fast and low-cost. And why limit ourselves to the atmosphere?

At NASA, I consider it our responsibility to push the technology frontier in all these areas.

Last July I issued a challenge before the Aero Club to work together and develop bold goals for the future. I felt we needed to reexamine our goals to be sure they supported the long-term health of America's air transportation system, and ultimately, our economy.

Over the next three months we met with industry leaders and others to define and quantify technology goals for continued leadership 50 years from now. In October, I gave an interim report to the aviation community at the World Aviation Congress to say, "This is where we are. What do you think?" The general consensus from industry, and especially from the CEO's present, was "Dan, your goals are not specific enough and they are not aggressive enough."

We listened, and now the culmination of our work is stated in ten goals. I call them "stretch goals" because they will stretch the boundaries of our knowledge and capabilities. I don't have time to go into detail on each goal, but as you leave today, we have our new Enterprise brochure available so you can read about them.

The ten goals of the Enterprise are framed by three technology "pillars," Global Civil Aviation, Revolutionary Technology Leaps, and Access to Space.

Global Civil Aviation focuses on our goals for safety, affordability, and the environ-mental compatibility for subsonic aircraft. Revolutionary Technology Leaps tackles these challenges for a new generation of both subsonic and supersonic aircraft.

In Access to Space, we will merge aeronautics technologies and operating principles with revolutionary new launch vehicle technologies. Again this is about how new transportation systems will open the doors for economic growth in new sectors such as space.

You'll notice that the goals are framed in terms of a final outcome, which is something that NASA does not control. We've stated the goals as the anticipated benefit of our technology once it has been incorporated by industry. As this implies, we cannot achieve these goals alone. Each will require partnership and coordination with manufacturers, airlines, the industry, DOD, and FAA.

In our Global Civil Aviation pillar, the number one goal is aviation safety.

This goal is to provide the technology that will reduce the aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 20 years.

In February, the President and the White House Commission on Aviation Safety and Security challenged NASA to assist in reducing fatal aircraft accident rates five-fold within ten years. This is a challenge not only for NASA, but a joint challenge for all of us, the FAA, DOD, and our industry partners. This will not be an easy goal, but it is a crucial one. I believe in it and NASA will spend a half billion dollars on this effort over the next 5 years.

People are concerned about safety, we read about it daily.

Experts predict that air traffic will double in 12 years and triple in 20. That's good news for the country. However, it won't be good unless we do something about flight safety. We had a major drop in jet aircraft accident rates in the 60's, but since then we have been not made significant improvements. The rate has been flat for the past 20 years!

The current aircraft hull-loss accident rate is 1.5 accidents per million departures worldwide. That sounds good and it is. Until air traffic triples in 20 years. If the rate of air traffic triples and we don't dramatically improve the safety rate, we're headed for major problems. I'm talking about one major air accident a week, like a few of the accidents we experienced last year. Imagine opening your paper every Tuesday morning to a weekly column to see what new airline catastrophe has happened in the world. It isn't a matter of statistics, it's a matter of perception. People who have never flown will refuse to do so. People who absolutely must, will be terrified. Eventually, companies will not be able to encourage people to fly and conduct business. It will shake the economy of the country. It's the domino effect. That is not the future I subscribe to. So we must do something about safety.

The major safety problem is human error, which is a factor in 60 to 70 percent of all aircraft accidents. Other major causes of accidents are mechanical problems, which account for roughly 17 percent, and then weather at about 5 percent. Therefore, one of the keys to improving aviation safety is to provide improved information for the human beings in

the system: the flight crew, air-traffic managers, aircraft maintenance and operations personnel.

Pilots need clear information on their situation. They need displays that provide information on the aircraft's condition and precise location, where other nearby aircraft are, and terrain and weather hazards. The objective is to avoid a crisis situation.

Information technology advances offer the opportunity for handling vast amounts of information in ways that were never before possible. The challenge is to apply this and other technologies to identify and display potential safety hazards so that they are avoided. For example, health monitoring systems are being developed to detect electrical or mechanical problems before they become serious. Global positioning system technology, already underway to avoid terrain, could be expanded to avoid other hazards such as dangerous weather conditions and other aircraft. Further breakthroughs will be achieved when this information can be used strategically, not just tactically, and distributed to the people who need it.

We know we cannot prevent human error. We can, however, provide a high level of confidence that the results of a human error will not lead to an accident.

So far we've made our planes safer. What's next?

Our second goal -- while maintaining safety, is to triple the aviation system throughput, in all weather conditions in 10 years.

It is estimated that congestion and delays at airports cost the American economy at least $4 billion a year. Four Billion! That again is not just the aviation industry. It's the cost to companies because their people are sitting in airports instead of doing their jobs. It's the costs that all of industry suffered from dealing with airport delays. And this is only going to get worse. Major airports are already showing the stress of more traffic than they can handle. What are we going to do when air traffic triples?

Just look at what a simple condition like fog can do. Right now, when fog occurs, the aircraft landing and takeoff spacings are increased and the rates are slowed down. That means delays. It costs money. Not just to us, who have a vested interest in the aviation industry -- but everyone.

National Airport in Washington, D.C., handles almost 900 arrivals and departures every day. When it has to close or reduce flights because of weather, that impacts everyone in this city. Turn on the news after a bad delay at National, it's covered by the press. Because it ripples through this town. That's one airport. But it doesn't stop with one airport. Delays at National affect flights at Pittsburgh and Boston and Chicago, and Denver. You get the picture.

With this goal, we are trying to triple the current capability under adverse weather conditions. This is within 10 years and targeted at the busiest airports. What that means is the planes will fly through fog as if it were a clear day.

If we can increase the capacity at airports that are overburdened, then more planes will fly. Right now, airports serving the 30 largest metropolitan areas generate more than $250 billion in economic activity, $80 billion in wages and support four million people in direct and indirect jobs. What will this mean for those 30 airports, and others, when we triple the demands on our system over the next two decades? Hopefully, it's a win-win proposition.

However, environmental concerns continue to impose limitations on our aviation system. Many airports have curfews because of aircraft noise, and in some locations, taxes are being imposed on aircraft emissions. In order to remove these limitations, we need to pursue technology for the future development of much quieter aircraft with lower engine emissions.

Our third goal is to reduce emissions of future aircraft by a factor of three within 10 years and by a factor of five within 20 years.

Our environmental goals are stretch goals. We have this goal on emissions, and a goal on noise. We publicize them to stimulate people, to stretch the imagination and the creativity of our researchers. We need to keep the global competition in mind, and we want to lead the way. We do not have the technology to meet the goals today and so they should not be used as a guide for unrealistic regulations. However, by pursuing these goals we will determine what is feasible and what is required, such that environmental regulations do not impose inappropriate safety or cost burdens.

I'd like to digress a minute to describe this with more technical detail -- particularly as it relates to our research for future supersonic transport

aircraft. In our High-Speed Research program we are using a parallel approach to address environmental impact.

On one hand we are developing impact assessments of aircraft emissions on the atmosphere, using scientific experts worldwide with the best aircraft, satellite, and computer tools available. These assessments will provide the information basis for establishing meaningful international emission standards.

On the other hand we are developing the technology for controlling emissions. This requires major advances in fuel and air mixture control and breakthough composite materials made of high-temperature ceramics for the combustor liner. We know we can achieve these ultra-low-emission goals in our labs, the challenge is to simplify the designs in order to also provide enhanced operability, reliability, and affordability for the real thing.

The need for quieter aircraft brings me to our fourth goal, to **reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 20.**

Imagine you are on the way to the airport. You're running late and as the shuttle bus drops you off, something catches your eye overhead. You look to see what it was. It's a jet. Nothing surprising about that. You are at an airport. The thing that is surprising, is that you didn't hear it. Even watching it overhead, the only noise you can hear is the rumble of the shuttle bus as it drives away.

With aircraft that quiet around airports, airlines can fly more, increasing the number of passengers they take every day. National Airport, which closes from 10 p.m. to 7 a.m. might stay open round the clock. There would be less congestion. There would be more business for the aviation industry. The benefits would trickle down to the business travelers and vacationers.

It is a great goal to work toward. NASA has conducted noise reduction research which is now being engineered into new aircraft. Further research with composites, engines, and airframes will help give us more design strategies for producing quieter aircraft.

Now I want to reemphasize the point I made earlier -- these environmental goals must be accomplished within our other goals for safety and

affordability. It is the combination of these three goals that will produce the most competitive aircraft for our Nation.

Our final global civil aviation goal is to reduce the cost of air travel by 25% within 10 years, and by 50% within 20 years.

In his speech before the World Aviation Congress in October, Phil Condit, the CEO of Boeing, showed a chart that just blew me away. It had two lines on it. One line was for revenue versus time, and the other was for aircraft cost versus time. From 1960 to 1980, the revenue and cost lines tracked very closely. Since then, they have separated dramatically. Starting around 1980, the chart showed a steep increase in aircraft cost, while revenue continued to decline. If we keep up this trend, providing air transportation will become unaffordable. It's imperative that things change. We have to get the costs down. That's why we have this goal.

So how are we going to do this? You don't just wave a magic wand and "poof" get lower cost aircraft. Affordability is a part of both Pillar One and Pillar Two.

A 25% improvement in cost may be achieved with advancements in materials, structures, aircraft systems, and manufacturing process technology. However, to achieve a 50% reduction in cost, we will need revolutionary changes. This leads us to our second pillar, Revolutionary Technology Leaps.

A goal in this pillar is to provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half.

The sooner we can help industry develop these aircraft, the quicker they'll be out there, competing for work around the globe at better prices, while costing less to operate and maintain.

These new tools will integrate multidisciplinary product teams, linking design, operations, and training databases to dramatically cut design cycle times. It's a long way from the days drafting boards with a sheet of paper and pencil. We're not quite there yet, but simulation-based design tools will provide incredible new capabilities. Technology like neural networks and artificial intelligence will help determine the best path to take in that difficult world of design.

Increasing the confidence in aircraft design as well as design of flight critical software will dramatically reduce costs associated with the certification of new aircraft. Again, safety and affordability will be enhanced.

On the flip side of the design-tool coin are experimental aircraft. I can't stress how important experimental aircraft are. They test and validate innovative, high-risk concepts. They allow us to accelerate the development into design and technology applications. The pioneering spirit at work in the X-1 and X-15 projects is being recaptured through the renewed emphasis of X-planes. The breakthrough work accomplished by future X-planes will move our country forward with an improved base of technical knowledge.

I've talked a lot about the big aircraft, now let's talk about the small aircraft. They play a very different, but very important role in our society.

The seventh goal is to invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 20 years.

General Aviation is a $15 billion industry, and an integral part of our national transportation system. General Aviation includes aircraft from long-range corporate jets to two and four passenger light aircraft. It provides on-the-spot efficient and direct air service that commercial aviation does not provide.

I believe general aviation can have a tremendous future in our country. We have seen a major decline in the last 20 years, but I think we can turn that around. In 1978, the general aviation manufacturers produced 17,811 planes. That number dropped to an all time low of 928 planes in 1994. Things started to turn around after the General Aviation Revitalization Act of 1994 which reduced the liability for GA manufacturers.

Let me tell you about the future I see for General Aviation: The safety of the light planes of the future will be far superior to traveling by car. These new aircraft should only cost about as much as today's high-end luxury automobile. Then businessmen, rural commuters, and small businesses can afford to fly routinely.

With fail-safe avionics, ultra-reliable engines, whole-airplane parachutes, and the simplifications enabled by "Free Flight," which allows pilots to choose their own routes, small airplanes can enjoy the levels of safety previously standard only on larger aircraft. The next generation of turbofan-powered general aviation aircraft will fly over 100 mph faster than today's aircraft. The reliability of these aircraft and avionics will be an order of magnitude better than for today's light planes.

One of the other major concerns, is the airports. Public use airports are lost at the alarming rate of 74 per year. That means every week at least one airport is closed. In just over 20 years, we lost almost 1500 public use airports. Once that runway is turned into a strip mall, it is gone forever. And if we have no runways, the advantage of flying general aviation aircraft will be lost. We need to get those aircraft in the skies and those runways regularly utilized while we still have them.

And we are taking action. Through our work on the Advanced General Aviation Transport Experiments (AGATE) consortium we have worked to develop glass cockpit technologies with graphic displays of weather and guidance information, along with on-board traffic avoidance systems. Our work through the General Aviation Propulsion (GAP) program will develop technologies and manufacturing processes for revolutionary low-cost environmentally-compliant new engine designs. With the infusion of new technology for safety, reliability and lower cost into the general aviation industry, I can see a boom ahead. I can imagine that future sales will make 1978 look like a lean year.

Getting people and cargo to their destinations is fundamental to our industry. In the global economy we are talking about greater distances and the need for speed. If we don't do it, someone else will.

That's why we have our eighth goal, to reduce the travel time to the Far East and Europe by 50% within 20 years, and do so at today's subsonic ticket prices.

America is a society with a vibrant economy, that allows us to have an exceptional standard of living. We out-travel everyone else on the globe by at least three to one for business and pleasure. The rest of the world does not live that way. But they are going to, and they are going to do it soon. The gross domestic product of the world is expected to grow by at least 3.2% annually. As the world economy expands, people in places like China,

Southeast Asia, and Russia are going to travel more and buy more imported goods.

World-wide, tourism is a $3 trillion per year business, employing 127 million people. Tourism is among the top 3 employers in 37 out of 50 of our states, and employs 8% of the total population. It contributes 6.4% to our gross domestic product. People want to travel, but they don't want to spend their time in transit. They want to get where they're going.

With the new High-Speed Civil Transport, we could go across the Pacific and back in the same day. If costs are similar to subsonic fares, it wouldn't be a hard choice on what to fly. For the airlines its a cost benefit too, to have that aircraft flying more revenue miles in the same period. Building a High Speed Civil Transport could provide the U.S. with $200 billion in sales, and 140,000 highly-skilled jobs, contributing to our economy and technological strength. So, where do we go from here? Is the sky really the limit? Let's go beyond the stratosphere and see what the future holds.

So, we come to our Access to Space pillar, where we have the last two goals.

The ninth goal is to reduce the payload cost to Low Earth Orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years.

We will reduce the cost of the access to space through our Reusable Launch Vehicle program. The Reusable Launch Vehicle program will benefit from system study capabilities, and the airframe, materials, and propulsion technology available through the aeronautics enterprise. This is why we've merged our aeronautics and advanced space transportation technology efforts into one Enterprise. The major benefits are reductions in program cost and risk. The benefit to the aeronautics program is an expansion of its capabilities and technological horizons.

We are already building hardware on the X-33, our prototype for a Reusable Launch Vehicle. We are on our way to reducing the probability of failure to one in 1,000. To put this in perspective, the probability of failure for today's Shuttle system is one in 145.

In addition, for the RLV we are looking for operational turn-around times of days, not months, with small ground crews similar to aircraft operations.

This is what we need to make space access an affordable and safe reality. This has obvious benefits to commercial users and to our national security.

The tenth and final goal is to reduce the payload cost to Low Earth Orbit by an additional order of magnitude, from $1,000's to $100's per pound, by 2020.

Our far-term research and development efforts will address a recognized need for a second order-of-magnitude reduction in cost. Some of the key requirements to making this work are high reliability - a probability of one failure in 1,000,000; low operating costs - about $300 per pound; quick turnaround - a matter of hours; and environmental compatibility with airfields.

One major technology advance, and another reason for combining aeronautics and space transportation technology is the use of air-breathing propulsion systems combined with rocket systems. Using some air avoids the need to carry all the oxidizer on board, significantly enhancing overall system performance, reducing vehicle size, and improving operational margins.

Once we accomplish our 10th goal and have truly affordable access to Low Earth Orbit, we can then use that technology to take the next big steps -- reaching out beyond Earth. We could be sending Low Earth Orbit spacecraft on regularly scheduled flights to a space station like the Pan Am shuttle in the movie "2001." From there, we could be using advanced concepts built on this technology to reach the moon. Is there water at the South Pole of the moon? If we could afford to send a team of geologists to explore the craters, we might find out the answer.

Once the cost of opening up the space frontier is no longer prohibitive, we could explore some of our neighboring planetary bodies. We could send people and equipment to Mars to search for more signs of life and the resources to support life. We could place a research station on an asteroid. One day, we could open up exploration throughout our solar system. Then, we could answer the questions that people have been asking about the distant planets since they were first discovered. We would have a renaissance -- about space and the knowledge and power it holds. It is our destiny.

But we must make the leap from expensive space flight, to low cost space flight. We must invest in the technology. We must invent the next

generation of launch vehicles and the ones after that. Those grandchildren of the vehicles we are working on today will make science fiction - science fact.

The key to the next era of exploration and expansion, beyond globalization, is to make access to space reliable, affordable, and safe. We must do it. We are going to do it.

These are our Three Pillars, with their ten challenging goals.

Leland Stanford and his associates stuck to their vision. They made it happen. We, NASA, will stick to our vision too. We like stretching the boundaries. We like proving that things that couldn't be done yesterday will be done tomorrow. We like making the extraordinary happen. But that's not the only reason we are doing this. America needs a vital, strong, competitive aerospace industry. We at NASA have a responsibility to help this Nation stay the world leaders, no matter what developments happen in the rest of the world. We want to be the best, and to stay the best.

The men driving the intercontinental railroad had five spikes to join the east to the west. We have our Three Pillars to connect the old way of air transportation to the new way. We are not ready to "plant them in the ground" and get our pictures taken. Not yet.

But like those men who changed America forever, who improved the travel time across the country, and invigorated businesses, we too are ready to stand up and say, "This is the way to make it happen."

Thank you.

Daniel S. Goldin
NASA Administrator

Remarks to Aero Club of Washington
3/20/97
Transcript
Washington, DC

Many in Congress have called NASA investment in aeronautics, "corporate welfare." How will you defend your vision against this kind of attack?

I think by communicating that this is a program, that if NASA doesn't do it, no one will do it. Let me explain to you what I mean.

I come from corporate America. In a 15-year period from the time I was really deeply involved in senior management in the corporation I came from and I ran the major portion of the R&D at that corporation, until the time I came to NASA, I saw R&D vista go from 15 years to 3.

The institutional investors put unbelievable pressure for near-term profits from American corporations. As a result, there is no corporation executive I know today that could go to the bank and say to an institutional investor, you know, I would like to change the crash rate on planes in 20 years from now and improve it by a factor of 10. I'd like to cut the emissions on planes by a factor of 5 in 20 years or I'd like to go figure out if I can build a supersonic transport which might cost $3 or 4 billion and maybe it'll take me 5 to 7 years to prove it and another 10 years to get it into production. There won't be one investment company in the world that would do that.

Now we say things about our federal government. This is a wonderful program; it is 80 years old. It is a partnership between the federal government and the American aerospace industry. Why do you think we are the leaders in the world? Because we do the long-term, high risk pre-competitive research and that's where we draw the line. We don't get into production, we don't get into manufacturing. To get a vision like this, no one corporation in America could have that vision and I've talked to CEO after CEO.

Let me say another thing about this. This is more than just commerce. There's an engine company in America that told me 70% of their business used to come from defense and 30% comes from commercial. Today it's 70% commercial and 30% defense and moving down real fast. If we believe in our country and we want our country to be strong into the 21st century, this is an issue that's crucial. We must have the strongest, most vital commercial aircraft industry in the world. Not only does our economy depend upon it, but our national security depends upon it.

If there's a problem, we have failed in communicating. I think the members of Congress that believe that, just haven't had an understanding and we will make sure they understand the issue. They believe in America, too, and we collectively need to do a better job in explaining it to the members of Congress.

Let me just say, we always get involved in these near-term questions. But tonight, go home and dream about what the future is going to be. Understand that the people in this room and the people in this great aerospace industry are going to change the future of this country. So that young people who never flew before will fly with confidence at Mach 2.4. Maybe some of those young people will fly at Mach 25.

But a nation that doesn't dream, that doesn't have a national team, is a nation that is headed in the wrong direction. That's not America. God bless you all.

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